The Effects of Long-Duration Spaceflight on Training Retention and Transfer

Human Research Program - Human Factors and Behavioral Performance
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ABSTRACT

Training our crew members for long duration, exploration-class missions will have to maximize long-term retention and transfer of the trained skills. The expected duration of the missions, our inability to predict all the possible tasks the crew will be called upon to perform, and the low training-to-mission time ratio require that the training be maximally effective such that the skills acquired during training will be retained and will be transferrable across a wide range of specific tasks that are different from the particular tasks used during training. However, to be able to design training that can achieve these ambitious goals, we must first understand the ways in which long-duration spaceflight affects training retention and transfer.

Current theories of training retention and transfer are largely based on experimental studies conducted at university laboratories using undergraduate students as participants. Furthermore, all such studies have been conducted on Earth. We do not know how well the results of these studies predict the performance of crew members. More specifically, we do not know how well the results of these studies predict the performance of crew members in space and especially during long-duration missions. To address this gap in our knowledge, the current on-going study seeks to test the null hypothesis that performance of university undergraduate students on Earth on training retention and transfer tests do in fact predict accurately the performance of crew members during long-duration spaceflights. To test this hypothesis, the study employs a single 16-month long experimental protocol with 3 different participant groups: undergraduate university students, crew members on the ground, and crew members in space. Results from this study will be presented upon its completion. This poster presents results of study trials of the two tasks used in this study: a data entry task and a mapping task.

By researching established training principles, by examining future needs, and by using current practices in spaceflight training as test beds, this research project is mitigating program risks and generating templates and requirements to meet future training needs.

Discussion

A typical high-risk, critical skill trained on the ground and refreshed onboard is cardiopulmonary resuscitation (CPR) (Figures 1 and 2). No data exists to determine how to support maximum retention of this skill, nor of how frequently this skill should be refreshed onboard. The fundamental research in this study is designed to provide data on training requirements that will support retention and transfer of trained skills and that apply not just to a single skill such as CPR but that apply across the entire training continuum (Figure 3) and across the breadth of crew training - from the medical emergency response shown here to system's emergencies, extravehicular activities, robotics operations, ascent/entry, maintenance, and repair.

Figure 1 *(left). Photo JSC2010-E-107015 Courtesy of NASA. ISS crew members Satoshi Furukawa, Mike Fossum, and Sergey Volkov train on cardiopulmonary resuscitation (CPR) in a 1-G ground training facility, pushing down onto a dummy strapped onto the crew medical restraint system (CMRS), the gold-colored platform.*

Figure 2 *(right). Photo ISS034-E-005260 Courtesy of NASA. ISS crew member Oleg Novitskiy demonstrates one method of performing CPR in 0-G onboard the ISS by pushing off the ceiling with his feet and down onto the CMRS.*

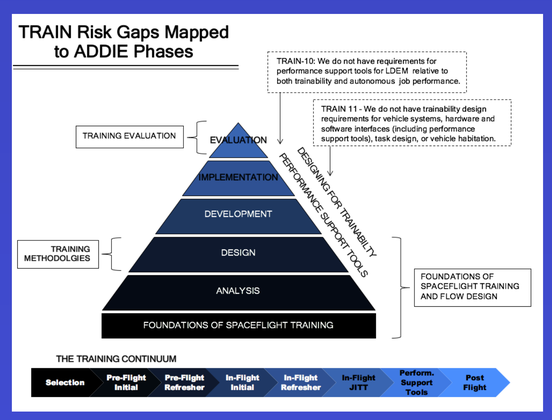
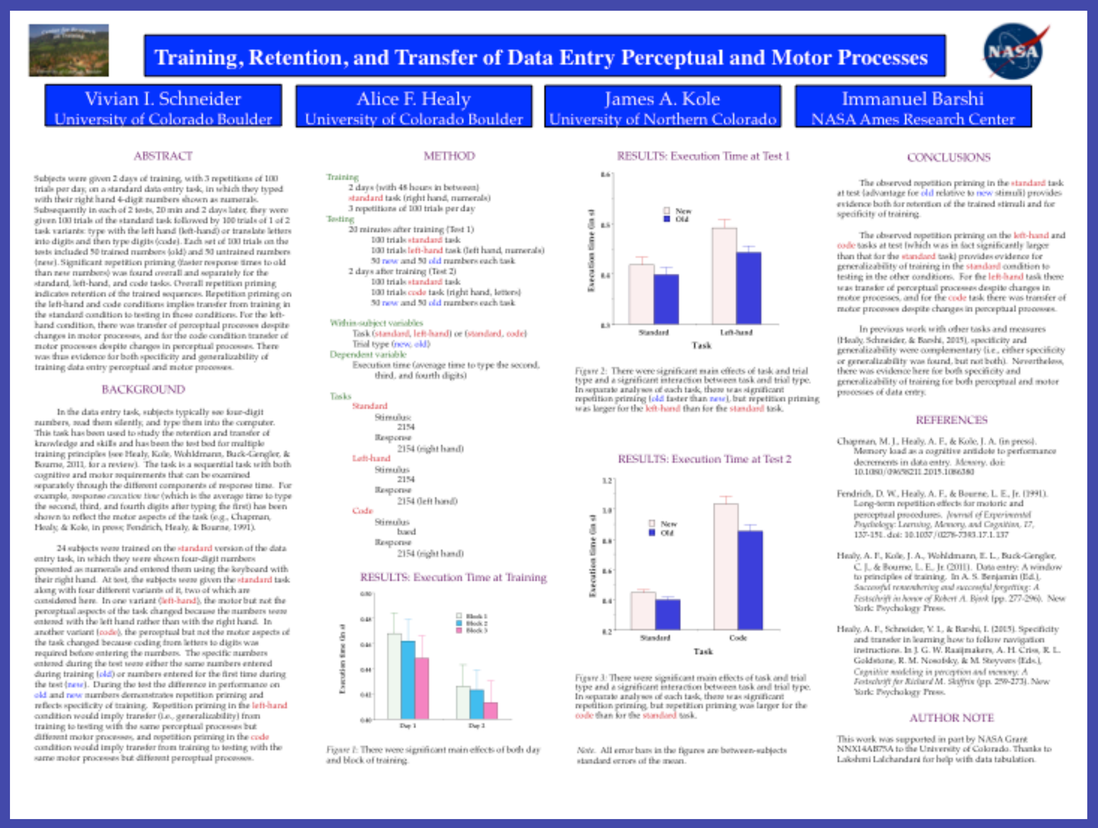


Figure 3*. The Risk of Performance Errors Due to Training Deficiencies path to risk reduction aligns with the standard ADDIE (analysis, design, development, implementation, evaluation) model for training design used by NASA's Flight Operations Directorate. The research encompasses the entire training continuum.*

Results from Related Trial Studies



Training, Retention, and Transfer of Data Entry Perceptual and Motor Processes

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ABSTRACT

Subjects were given 2 days of training, with 3 repetitions of 100 trials per day, on a standard data entry task, in which they typed with their right hand 4-digit numbers shown as numerals. Subsequently in each of 2 tests, 20 min and 2 days later, they were given 100 trials of the standard task followed by 100 trials of 1 of 2 task variants: type with the left hand (left-hand) or translate letters into digits and then type digits (code). Each set of 100 trials on the tests included 50 trained numbers (old) and 50 untrained numbers (new). Significant repetition priming (faster response times to old than new numbers) was found overall and separately for the standard, left-hand, and code tasks. Overall repetition priming indicates retention of the trained sequences. Repetition priming on the left-hand and code conditions implies transfer from training in the standard condition to testing in those conditions. For the left-hand condition, there was transfer of perceptual processes despite changes in motor processes, and for the code condition transfer of motor processes despite changes in perceptual processes. There was thus evidence for both specificity and generalizability of training data entry perceptual and motor processes.

BACKGROUND

In the data entry task, subjects typically see four-digit numbers, read them silently, and type them into the computer. This task has been used to study the retention and transfer of knowledge and skills and has been the test bed for multiple training principles (see Healy, Kole, Wohldmann, Buck-Gengler, & Bourne, 2011, for a review). The task is a sequential task with both cognitive and motor requirements that can be examined separately through the different components of response time. For example, response execution time (which is the average time to type the second, third, and fourth digits after typing the first) has been shown to reflect the motor aspects of the task (e.g., Chapman, Healy, & Kole, in press; Fendrich, Healy, & Bourne, 1991).

24 subjects were trained on the standard version of the data entry task, in which they were shown four-digit numbers presented as numerals and entered them using the keyboard with their right hand. At test, the subjects were given the standard task along with four different variants of it, two of which are considered here. In one variant (left-hand), the motor but not the perceptual aspects of the task changed because the numbers were entered with the left hand rather than with the right hand. In another variant (code), the perceptual but not the motor aspects of the task changed because coding from letters to digits was required before entering the numbers. The specific numbers entered during the test were either the same numbers entered during training (old) or numbers entered for the first time during the test (new). During the test the difference in performance on old and new numbers demonstrates repetition priming and reflects specificity of training. Repetition priming in the left-hand condition would imply transfer (i.e., generalizability) from training to testing with the same perceptual processes but different motor processes, and repetition priming in the code condition would imply transfer from training to testing with the same motor processes but different perceptual processes.

METHOD

Training
2 days (with 48 hours in between)
standard task (right hand, numerals)
3 repetitions of 100 trials per day

Testing
20 minutes after training (Test 1)
100 trials standard task
100 trials left-hand task (left hand, numerals)
50 new and 50 old numbers each task
2 days after training (Test 2)
100 trials standard task
100 trials code task (right hand, letters)
50 new and 50 old numbers each task

Within-subject variables
Task (standard, left-hand) or (standard, code)
Trial type (new, old)

Dependent variable
Execution time (average time to type the second, third, and fourth digits)

Tasks
Standard
Stimulus: 2154
Response: 2154 (right hand)
Left-hand
Stimulus: 2154
Response: 2154 (left hand)
Code
Stimulus: baed
Response: 2154 (right hand)

RESULTS: Execution Time at Test 1

Figure 2. There were significant main effects of task and trial type and a significant interaction between task and trial type. In separate analyses of each task, there was significant repetition priming (old faster than new), but repetition priming was larger for the left-hand than for the standard task.

RESULTS: Execution Time at Test 2

Figure 3. There were significant main effects of task and trial type and a significant interaction between task and trial type. In separate analyses of each task, there was significant repetition priming, but repetition priming was larger for the code than for the standard task.

Note. All error bars in the figures are between-subjects standard errors of the mean.

RESULTS: Execution Time at Training

Figure 1. There were significant main effects of both day and block of training.

CONCLUSIONS

The observed repetition priming in the standard task at test (advantage for old relative to new stimuli) provides evidence both for retention of the trained stimuli and for specificity of training.

The observed repetition priming on the left-hand and code tasks at test (which was in fact significantly larger than that for the standard task) provides evidence for generalizability of training in the standard condition to testing in the other conditions. For the left-hand task there was transfer of perceptual processes despite changes in motor processes, and for the code task there was transfer of motor processes despite changes in perceptual processes.

In previous work with other tasks and measures (Healy, Schneider, & Barshi, 2015), specificity and generalizability were complementary (i.e., either specificity or generalizability was found, but not both). Nevertheless, there was evidence here for both specificity and generalizability of training for both perceptual and motor processes of data entry.

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AUTHOR NOTE

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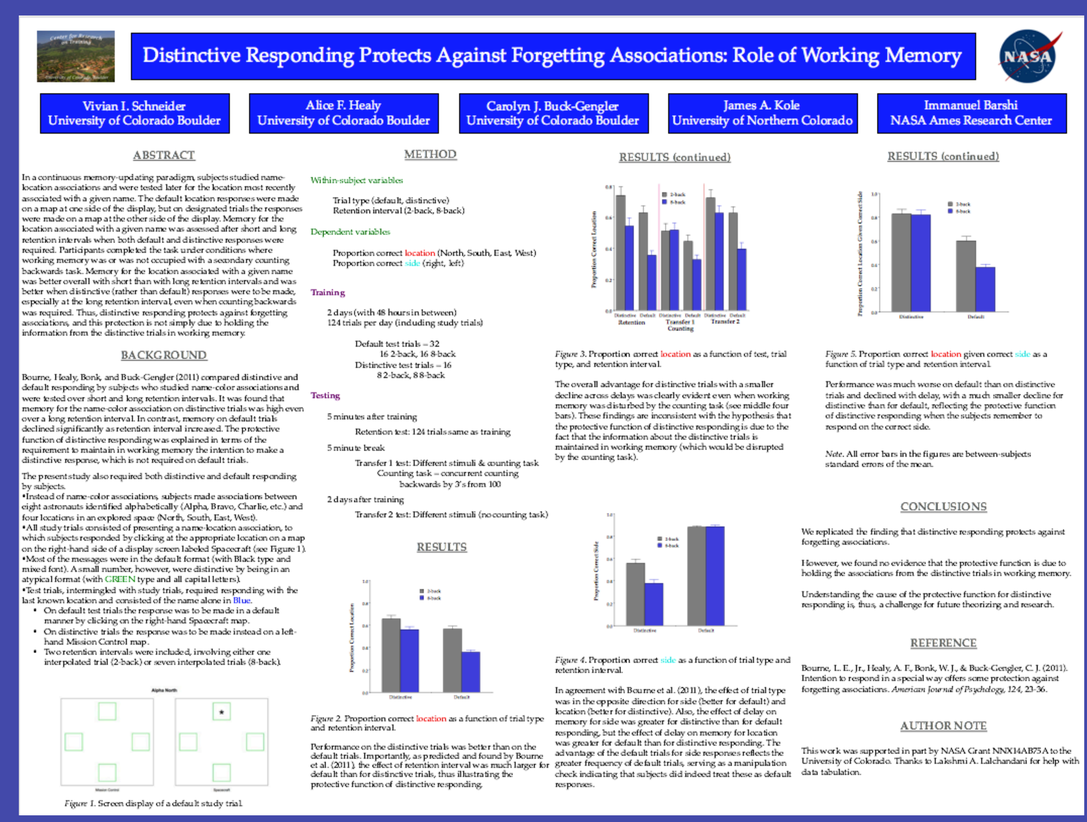

Distinctive Responding Protects Against Forgetting Associations: Role of Working Memory

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ABSTRACT

In a continuous memory-updating paradigm, subjects studied name-location associations and were tested later for the location most recently associated with a given name. The default location responses were made on a map at one side of the display, but on designated trials the responses were made on a map at the other side of the display. Memory for the location associated with a given name was assessed after short and long retention intervals when both default and distinctive responses were required. Participants completed the task under conditions where working memory was or was not occupied with a secondary counting backwards task. Memory for the location associated with a given name was better overall with short than with long retention intervals and was better when distinctive (rather than default) responses were to be made, especially at the long retention interval, even when counting backwards was required. Thus, distinctive responding protects against forgetting associations, and this protection is not simply due to holding the information from the distinctive trials in working memory.

BACKGROUND

Bourne, Healy, Bonk, and Buck-Gengler (2011) compared distinctive and default responding by subjects who studied name-color associations and were tested over short and long retention intervals. It was found that memory for the name-color association on distinctive trials was high even over a long retention interval. In contrast, memory on default trials declined significantly as retention interval increased. The protective function of distinctive responding was explained in terms of the requirement to maintain in working memory the intention to make a distinctive response, which is not required on default trials.

The present study also required both distinctive and default responding by subjects.
•Instead of name-color associations, subjects made associations between eight astronauts identified alphabetically (Alpha, Bravo, Charlie, etc.) and four locations in an explored space (North, South, East, West).
•All study trials consisted of presenting a name-location association, to which subjects responded by clicking at the appropriate location on a map on the right-hand side of a display screen labeled Spacecraft (see Figure 1).
•Most of the messages were in the default format (with Black type and mixed font). A small number, however, were distinctive by being in an atypical format (with GREEN type and all capital letters).
•Test trials, intermingled with study trials, required responding with the last known location and consisted of the name alone in Blue.
- On default test trials the response was to be made in a default manner by clicking on the right-hand Spacecraft map.
- On distinctive trials the response was to be made instead on a left-hand Mission Control map.
- Two retention intervals were included, involving either one interpolated trial (2-back) or seven interpolated trials (8-back).

Figure 1. Screen display of a default study trial.

METHOD

Within-subject variables
Trial type (default, distinctive)
Retention interval (2-back, 8-back)

Dependent variables
Proportion correct location (North, South, East, West)
Proportion correct side (right, left)

Training
2 days (with 48 hours in between)
124 trials per day (including study trials)
Default test trials – 32
16 2-back, 16 8-back
Distinctive test trials – 16
8 2-back, 8 8-back

Testing
5 minutes after training
Retention test: 124 trials same as training
5 minute break
Transfer 1 test: Different stimuli & counting task
Counting task – concurrent counting backwards by 3's from 100
2 days after training
Transfer 2 test: Different stimuli (no counting task)

RESULTS

Figure 2. Proportion correct location as a function of trial type and retention interval.

Performance on the distinctive trials was better than on the default trials. Importantly, as predicted and found by Bourne et al. (2011), the effect of retention interval was much larger for default than for distinctive trials, thus illustrating the protective function of distinctive responding.

RESULTS (continued)

Figure 3. Proportion correct location as a function of test, trial type, and retention interval.

The overall advantage for distinctive trials with a smaller decline across delays was clearly evident even when working memory was disturbed by the counting task (see middle four bars). These findings are inconsistent with the hypothesis that the protective function of distinctive responding is due to the fact that the information about the distinctive trials is maintained in working memory (which would be disrupted by the counting task).

Figure 4. Proportion correct side as a function of trial type and retention interval.

In agreement with Bourne et al. (2011), the effect of trial type was in the opposite direction for side (better for default) and location (better for distinctive). Also, the effect of delay on memory for side was greater for distinctive than for default responding, but the effect of delay on memory for location was greater for default than for distinctive responding. The advantage of the default trials for side responses reflects the greater frequency of default trials, serving as a manipulation check indicating that subjects did indeed treat these as default responses.

RESULTS (continued)

Figure 5. Proportion correct location given correct side as a function of trial type and retention interval.

Performance was much worse on default than on distinctive trials and declined with delay, with a much smaller decline for distinctive than for default, reflecting the protective function of distinctive responding when the subjects remember to respond on the correct side.

Note. All error bars in the figures are between-subjects standard errors of the mean.

CONCLUSIONS

We replicated the finding that distinctive responding protects against forgetting associations.

However, we found no evidence that the protective function is due to holding the associations from the distinctive trials in working memory.

Understanding the cause of the protective function for distinctive responding is, thus, a challenge for future theorizing and research.

REFERENCE

Bourne, L. E., Jr., Healy, A. F, Bonk, W. J., & Buck-Gengler, C. J. (2011). Intention to respond in a special way offers some protection against forgetting associations. *American Journal of Psychology, 124*, 23-36.

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Current State:

- The study with university students employing the 16-month long experimental protocol is nearing completion. Sample results from related studies employing the two experimental tasks are displayed in the two insert-posters here.
- *An identical study with crew members on the ground is planned for this year (2017).*
- *An identical study with crew-like participants is planned for this year (2017).*
- *An identical study with crew members on board the ISS is pending.*

Implications:

Results from this study have direct implications to various NASA requirements and guidance documents such as the ones shown here.

NASA Space Flight Human-System Standard Volume 1: Crew Health

NASA Technical Standard

July 30, 2014

NASA Space Flight Human-System Standard Volume 2: Human Factors, Habitability, and Environmental Health

NASA Technical Standard

February 10, 2015

Exploration Medical Capabilities Concept of Operations

Human Research Program

In Progress

Flight Operations Directorate Spaceflight Personnel Certification Plan

Flight Operations Directorate

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